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FLEET NUMERICAL WEATHER FACILITY
U. S. NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA
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I. SUMMARY

This report outlines present programs and future plans for numerical analysis and forecasting of the air/ocean environment at this activity. The Operations Schedule, Operational Program Descriptions and Data Handling Programs (160A) sections are presented in greater detail in order that operational users and computer network stations may obtain a better understanding of how the products are derived and the approximate time they are available for dissemination. → next page

The report does not go into detail in other areas which have been adequately covered by previous progress or special reports.

II. BACKGROUND

The following mission has been assigned to the Fleet Numerical Weather Facility by the Secretary of the Navy:

1. Provide numerical weather products on an operational basis peculiar to the needs of the Naval Establishment.
2. Continue to develop and test numerical techniques in meteorology and oceanography applicable to Naval Weather Service analysis and forecasting problems.

The methods of attack used have been a combination of theoretical equations with proven synoptic - empirical principles. The atmosphere and the oceans are treated as one environment; particular attention is directed toward the effects of interaction between the two media which constitute the naval environmental operating area. Extensive comparison with observed features and their time variation in both the atmosphere and the ocean is used to establish the acceptability of analysis and forecast models. A model becomes operational when overall results are equal to or better than those obtained through hand techniques.

In the past, most products were distributed directly to the user from the Monterey Facility. Now that FWC, Suitland and FWC, Pearl have become part of the computer network, the procedure has been modified so that Monterey makes the basic analyses and forecasts (usually hemispheric), derives the more complex byproducts, and then sends large area data fields or charts to the Weather Centrals for final computation and/or dissemination to fleet units and shore commands.

Monterey will carry out computation of those environmental parameters needed as input to other problems. Further computation required to make an operational decision, to determine equipment capabilities, or to correct equipment settings is properly the responsibility of other activities.

As the Naval Weather Service computer network develops further, it is expected that raw data will be partially edited by outlying centers before transmission to Monterey at high speed. Time schedules will be shortened, and with the addition of a second computer at FNWF, numerical products should be available well ahead of the present Operations Schedule.

III. OPERATIONS SCHEDULE

This schedule is intended to list chronologically the programs presently being run on an operational basis and further to acquaint the users with an indication as to when and what numerical products are available for local use or for incorporation into the facsimile network.

Unless the products listed below are specifically called "list" or "message," it may be assumed that they are in "chart" form and must be "processed" by the "PLOT" program before they are ready for transmission. Consequently a number of charts may be accumulated before plotting at which time all the charts would be available simultaneously. Lists and messages are normally ready for transmission at the end of a program.

Although every effort has been made to make the "times" realistic, some deviation is bound to occur and this fact should be considered in establishing local deadlines.

For a more detailed description of basic programs, see Section IV.

Users are also reminded that even though most of the listed products are "charts" of the Northern Hemisphere, single or groups of parameters can be extracted for any grid point or any five-degree latitude/longitude intersection and compiled into a single teletype message.

FNWF Program (Abbreviation)	Purpose	Product	Note[1] Time Completed
(Begin Operational Run)	-	-	0500
1604 REGAP	convert TTY to BCD. Breaks data into shorter records		0506
Automatic Data Processing (ADP)	initial data reduction	-	0540
Post-Processing (P-P)	position check of ships	current & past positions of ships by long/lat-list	0544
Surface Pre-Analysis (Pre-Anal)	data reduction & sorting	-	0550
Surface Analysis (Sfc Anal)	generate surface chart	surface analysis	0603
Sea Temperature Analysis (SST)	produce sea temperature analysis	sea temperature analysis	0607
Plot (Plot) Note[2]	convert charts to series of pen instructions to drive plotter	plotter map	0612
Upper Air ADP (UA-ADP) (includes 1604 REGAP)	continuation of initial ADP	-	0622

Notes: [1] Listed times (Zulu) are for an average 00/06Z OPS run. Add 12 hours for comparable 12/18Z run.

[2] The Plot program takes about 1.6 minutes for each chart. This program is run periodically throughout the run. Hereafter only the symbol [[P]] will be listed with a program to indicate that plotting is done after that program. Times listed will include plotting time for all charts up to this time.

Upper Air Pre-Analysis (UAPA)	initial check and sort of upper air reports	-	0630
Upper Air Analysis (UAA)	analyze upper air levels from 1000 mb to 200 mb. Checks for incomplete soundings and missing stations.	4 stability charts 850 mb Ht. analysis 850 mb Temp. " 700 mb Ht. " 700 mb Temp. " 500 mb Ht. " 500 mb Temp. " 400 mb Ht. " 400 mb Temp " 300 mb Ht. " 300 mb Temp. " 200 mb Ht. " 200 mb Temp. " [[P]]	0710
Strato Analysis (Strato Anal)	extrapolate upper air analysis to 10 mb	100 mb Ht. & Temp. 50, 30 & 10 mb Ht.	0715
Vertical Motion Analysis (VM)	compute large scale vertical motions	PTer Anal. (Press. of Terrain) 850 mb vert. mot. anal. 500 mb vert. mot. anal.	0719
Upper Air Forecast (UA Fcst)	barotropic forecast	12 hr. 500 mb fcst 24 hr. 500 mb fcst 36 hr. 500 mb fcst 48 hr. 500 mb fcst 60 hr. 500 mb fcst 72 hr. 500 mb fcst [[P]]	0751

Hurricane and Typhoon Steering (HAT) (Run on request only)	forecast movement of hurricanes and typhoons	steering - message	6 min./ storm
500 MB HI/LO Message	extracts position of 500 mb highs and lows, and puts them in message format	500 mb HI/LO msg	0755
Wind Analysis (Wind Anal)	compute geostrophic wind speed and direction. (Can produce values up to 10 mb)	700 mb wind direction 500 mb " " 300 mb " " 200 mb " " 700 mb isotachs 500 mb " 300 mb " 200 mb "	0801
General Address Message (GAM) 7/5/3/2 Analysis	extracts HH, DD & I for selected points and combines into message	7/5/3/200 mb Ht., Dir. & Speed message	0805
Analysis Strato Winds	computes winds every 5000 feet from surface to 100,000 feet	-	0808
Anal. Strato Winds Message	extract data from previous program for selected areas	strato anal. message	0810
HAT Zonal Wind Message (HAT Z.W.)	24 hr. forecast zonal wind profiles	zonal wind message	0813

Space Mean (Sp. Mean)	generates space mean and vorticity charts	500 mb space mean 24 hr. 500 mb " " 48 hr. 500 mb " " 72 hr. 500 mb " " 500 mb vorticity 24 hr. 500 mb " 48 hr. 500 mb " 72 hr. 500 mb " space mean message	0819
Isotach Forecast	computes 500 mb isotach forecasts	24 hr. 500 mb wind direction 48 hr. 500 mb " " 72 hr. 500 mb " " 24 hr. 500 mb isotach 48 hr. 500 mb " 72 hr. 500 mb "	0822
Isotach Forecast Message	extracts and combines data into message format	24/48/72 hr. 500 mb isotach message	0826
Cyclone Forecast	forecasts cyclone movements	cyclone message	0831
Surface Forecast	dynamical forecast	-	0853
Sea Level Pressure Forecast (SLP)	combined statistical and dynamical forecast	12 hr. surface forecast 24 hr. " " 36 hr. " " 48 hr. " " [[P]]	0857

Multi-Layer Forecast (M-L Fcst)	interpolate surface and 500 mb forecast to obtain forecasts for other levels	12 hr. 850 mb Ht. 12 hr. 700 mb Ht. 12 hr. 400 mb Ht. 12 hr. 300 mb Ht. 12 hr. 200 mb Ht. 12 hr. 100 mb Ht. 12 hr. 50 mb Ht. 24 hr. 850 mb Ht. 24 hr. 700 mb Ht. 24 hr. 400 mb Ht. 24 hr. 300 mb Ht. 24 hr. 200 mb Ht. 24 hr. 100 mb Ht. 24 hr. 50 mb Ht. 24 hr. 30 mb Ht. 24 hr. 10 mb Ht. 36 hr. 850 mb Ht. 36 hr. 700 mb Ht. 36 hr. 400 mb Ht. 36 hr. 300 mb Ht. 36 hr. 200 mb Ht. 36 hr. 100 mb Ht. 36 hr. 100 mb Temp. 36 hr. 50 mb Ht. 36 hr. 30 mb Ht. 48 hr. 850 mb Ht. 48 hr. 700 mb Ht. 48 hr. 300 mb Ht. 48 hr. 200 mb Ht. [[P]]	0920

Multi-Layer Winds (M-L Wind)	computes geostrophic winds from M-L Fcst	12 hr. 850 mb DD 12 hr. 850 mb I 12 hr. 700 mb DD 12 hr. 700 mb I 12 hr. 500 mb DD 12 hr. 500 mb I 12 hr. 400 mb DD 12 hr. 400 mb I 12 hr. 300 mb DD 12 hr. 300 mb I 12 hr. 200 mb DD 12 hr. 200 mb I 24 hr. 850 mb DD 24 hr. 850 mb I 24 hr. 700 mb DD 24 hr. 700 mb I 24 hr. 500 mb DD 24 hr. 500 mb I 24 hr. 400 mb DD 24 hr. 400 mb I 24 hr. 300 mb DD 24 hr. 300 mb I 24 hr. 200 mb DD 24 hr. 200 mb I 36 hr. 850 mb DD 36 hr. 850 mb I 36 hr. 700 mb DD 36 hr. 700 mb I 36 hr. 500 mb DD 36 hr. 500 mb I

(M-L Wind) (continued)		36 hr. 400 mb DD 36 hr. 400 mb I 36 hr. 300 mb DD 36 hr. 300 mb I 36 hr. 200 mb DD 36 hr. 200 mb I 36 hr. 100 mb DD 36 hr. 100 mb I 36 hr. 50 mb DD 36 hr. 50 mb I 36 hr. 30 mb DD 36 hr. 30 mb I	0928
700/500/300/200 MB Forecast Message (7/5/3/2 Fcst)	24 & 36 hr. fcst of HH, DD, I for four levels	7/5/3/2 fcst message	0935
500/300 Wind Message	compile data for message	5/3 wind message	0938
Strato Forecast Winds	compute forecast winds every 5000 feet from surface to 1000,000 feet	-	0943
Strat Forecast Winds Message	extract data from previous program and put into message format	strato forecast winds message	0947
Effective Fallout Winds (EFW)	produce fallout winds message	RADFO messages (Number is variable)	0954
Vertical Motion Forecast (VM)	forecasts large scale vertical motion	36 hr. PTer (press. of terrain) 36 hr. 850 mb VM fcst 36 hr. 500 mb VM fcst [[P]]	1015

1604 REGAP	(same as first group of programs)		1019
06Z ADP	(" " " " " "	)	1034
P-P	(" " " " " "	)	1039
Pre-Anal	(" " " " " "	)	1043
Sfc Anal	(" " " " " "	) sfc. analysis	1055
Ocean Winds	compute winds for waves	-	1058
Wave Analysis/Forecast	*produces wave charts*	Anal/30 Prog Swell Height Anal/30 Prog Swell Direction Anal/30 Prog Swell Period Anal/30 Prog Wind Wave Height Anal/30 Prog Wind Wave Direction Anal/30 Prog Wind Wave Period Anal/30 Prog Combined Height Anal/30 Prog Combined Direction Anal/30 Prog Combined Period	1110
General Mixed Layer Depth (GMLD)	generates hemispheric layer depth chart	layer depth analysis	1800Z only
Mixed Layer Depth Message (MLD MSG)	produces a "30 hour ocean" forecast message	30 hour ocean fcst msg	1800Z only

Wave Message (GAM)	compacts wave data into message format	wave messages (number varies) (anal & prog) [[P]]	1145
BETA (BETA)	divide 500 mb flow into two parts - disturbance & residual	1000 mb SD 1000 mb SR 500 mb SD 500 mb SR 500 mb SL 24 hr. 500 mb SD 24 hr. 500 mb SR 24 hr. 500 mb SL 48 hr. 500 mb SD 48 hr. 500 mb SR 48 hr. 500 mb SL [[P]]	1222
San Diego Cps	to compute mixed layer depth and generate message	SOCAL Message	1230
HEAPS Program	to compute mixed layer depth and generate message	HEAPS Message	1239
Verification	compares analysis against forecast	500 - 1000 thickness anal. 500 mb verification surface verification [[P]]	1256

IV. OPERATIONAL PROGRAM DESCRIPTIONS

This section will not go into the long, complicated programs needed to identify, sort, check and process the thousands of raw data reports used in numerical analysis and forecasting. These routines are listed at the beginning of the Operations Schedule and are usually referred to as Automatic Data Processing (ADP). Since, however, this processing requires a considerable portion of a day's operations, all Centrals, Facilities and other relay points are enjoined to forward data collections in standard, clean, identifiable format. Nonstandard headings, missed headings, and code deviations do nothing but slow down the return of processed products to the user.

Basic meteorological and oceanographic programs resulting in an analysis and/or forecast will be described in sufficient detail for the user to obtain a general understanding of the model used. Derived products will be discussed in less detail; the paragraphs on messages will summarize contents of the original promulgating instructions.

A. METEOROLOGY (Basic)

1. Surface Analysis - In the surface analysis, all surface pre-analysis and ADIS programs are used. The observation time of each report is checked and only reports within ± one hour of analysis time (00Z, 06Z, 12Z or 18Z) are used. Then the list is checked for two or more reports from the same station with reported pressures within ± one millibar. These are tagged as duplicates and only one retained.

The next step in the analysis is to check the reported pressures for gross errors. A "guess" field, coverage field, and the current month's climatology are read into the computer. The "guess" field is the latest available surface forecast verifying at the analysis time, usually a six-hour forecast and in no case more than a twelve-hour forecast. The coverage field shows the areas where good surface reports were received for the previous six-hour analysis. Since the forecast field used as a guess is best where the data coverage for the analysis from which it is made is good, the "guess" field in these areas is left unmodified. However, in areas where there was poor coverage on the previous analysis, the difference between the forecast field and the climatological field is computed and a small part of this difference is added to the "guess" field, slightly modifying it in the direction of the climatological value.

After the "guess" field has been so modified, a tolerance field is introduced. This tolerance field varies from four millibars near the equator to approximately twenty millibars in areas of maximum pressure changes and areas where the maximum errors occur in the surface forecasts. If the absolute value of the difference between the reported pressure and the "guess" field value interpolated to its location is greater than the tolerance value at this point, the report is marked as a reject.

After all reports have been checked, the winds of ships not rejected are used to provide four extrapolated reports in areas of sparse data. The wind as reported is first turned fifteen degrees towards higher pressure to approximate a geostrophic wind. Then the distance to the next closest report is calculated. If there is another report within one-half of a grid length the report is not extrapolated. If the closest report is more than one-half grid length distant, two reports with the same pressure as the ship report are placed on either side of the ship report one-half of this distance parallel to the wind direction, and two reports with pressures calculated to give the gradient necessary to support the reported wind speed are placed one-fourth of this distance normal to the wind direction. The maximum distances these extrapolated reports are placed are one grid length parallel (one-half grid length normal) to the wind direction.

The extrapolated reports are gross-error-checked in the same way as other reports.

The modified "guess" field used for the gross-error-checking is also used as the first approximation to the analysis itself. Before the actual analysis cycle begins, the central pressures and location of cyclones in ocean areas of sparse coverage are put in the data list by the duty officer. The reports are analyzed using Carstensen's Analysis Program for randomly spaced data. Except for the first pass through the program a fitting check is performed to further reject bad reports in the middle of each subsequent pass. Each report is, in turn, withheld and an analysis of the sixteen surrounding points is performed without the report being used. The difference between the reported pressure and the value given at its location by this analysis is compared against a tolerance field similar to the one used in the gross-error-checking except that these tolerances are decreased after each cycle through the analysis program. In this way a report which does not agree with other reports in its area is rejected. After several cycles through this analysis program, all reports not marked as rejects have been "drawn to" and the final analysis is written on magnetic tape for plotting and transmission.

2. Upper Air Analysis - The upper air analysis is carried out in the standard FNWF 63x63 grid-point field on a polar stereographic projection. The equator is an inscribed circle in this grid; however, those grid points south of 2°N are held constant during the analysis operation.

The vertical structure of an atmospheric column up to the 200-mb level is modeled so that it can be defined in terms of the 1000-mb height, the 1000-500-mb thickness, and the stability in five selected layers (1000-775, 775-600, 600-450, 450-300, 300-200 mb). With only occasional exceptions, this method of modeling provides resolution of D-values at any level between 1000 and 200 mb within the limits of known instrumental errors. The analysis of parameter fields in the horizontal is further controlled by the usual physical constraints such as the geostrophic relationship, dynamic instability limits, etc.

A general purpose analysis program for a two-dimensional field of scalar quantities is used for each field to be analyzed. Winds are introduced where appropriate by converting them to scalar D-value gradients. The analysis program has the feature that the analyses can be made to fit some classes of data to a closer tolerance than that required for other classes of data. What the two-dimensional analysis program attempts to do is to adjust a first guess to fit the new data while preserving the Laplacian of the first guess in regions where this does not conflict with observations. A degree of smoothing which can be specified by program parameters is also introduced. The analysis program has authority to reject any piece of data not compatible with nearby information.

In carrying out the analysis, surface pressure reports, which are received earlier, are processed first. The surface data includes airways and synoptic land reports for a three-hour span centered at map time. Ship reports to ± three hours are used, the off time ones being slightly displaced according to the large-scale "steering" wind. Winds from ships are converted into a set of four pressure values around the ship. For low pressure centers located over oceans, where data coverage may be sparse, some hand-constructed bogus surface pressures are entered at the discretion of the meteorological officer on watch. This is the only human intervention in the entire analysis cycle, and for best results it has been found necessary to give the analysis program authority to reject even this offer of help at its own discretion. The first guess for the analysis is a six-hour forecast from the preceding analysis.

Rejection of gross errors especially in regions of sparse data is a serious problem, but is one adequately treated with the aid of several fitting checks.

The raobs are next checked for vertical consistency of pressure and virtual temperature at the mandatory levels. In checking the vertical consistency of a sounding there is enough redundancy in the sounding report so that usually several missing or incorrect values may be recomputed. Additional gross error checks are carried out at the 1000-mb and 500-mb levels to examine whether a raob with the reported pressure and temperature may plausibly be located at the reported position.

The first guess for the analysis of the 500-mb D-values is an arithmetic average of two rather independent estimates of approximately equal skill. One of these is the twelve-hour forecast of the 500-mb D-values from the previous analysis. The other is constructed from a simple forecast thickness 1000 - 500 mb together with the new current analysis of the surface chart.

A sensitive determination of the stabilities can be made usually only where there are vertical soundings; that is, at raob locations. The horizontal analysis of stabilities is carried out with the constraint that static instability is not allowed at any grid point. The first guess for the stability analysis is that analyzed at the preceding twelve-hour map time. From the surface pressure field, the thickness field, and the five stability fields, it is possible to obtain a value of D or T for any point below the 200-mb level consistent with all accepted data and without risk of static instability.

Introduction of spot level data such as an aircraft wind report at an arbitrary level gives rise to certain problems which require careful treatment. One basic difficulty is the gross error check. One must attempt to distinguish between an isolated report of unanticipated conditions and an erroneous isolated report. Another difficulty is that in casually introducing a spot value somewhere in the troposphere, the entire vertical structure may require revision if vertical consistency is to be retained.

A spot value somewhere in the troposphere is usually less accurate than the existing analyzed sea level pressure and has little value in modifying that field. A spot value should not be expected to contain any information as to stability, so it is of negligible value in modifying the stability analyses. The appropriate role of a spot value is to modify the mean temperature of the troposphere at its geographical location. This is done by modifying the thickness analysis so that the spot value computed from the vertical structure model becomes equal to the reported value at its location in space. In this form the spot information is reconciled with other nearby information and honored or rejected as appropriate.

In large silent data areas it would be possible for the analysis to drift gradually over a period of days to impossible values. To prevent this a routine is included to return areas of no data coverage a fraction of the way toward climatological values.

In summary this system carries out the analysis of the troposphere in terms of a pressure level, a mean temperature, and a stability structure. Forecasts are employed in the analysis where they appear to be useful. In silent areas where forecasts are of little value because they in turn were not based on data, a partial return toward climatology is introduced. Although not yet fully developed, the process of going from observations to analysis is now satisfactory.

3. Pattern Separation - Standard methematical tools such as Fourier series or Legendre polynomials are not very attractive for separation of scales of motion. There have been numerous attempts to develop methods for extraction of certain features from the total flow for restricted purposes and some of these have been quite successful. Holl has outlined a general numerical procedure for scale and pattern decomposition which has been applied at Monterey on a daily basis for a number of months. In this procedure, specification of several parameters controls the scale to which separation is carried out. The method consists of repeated application of a smoothing operator which reduces first the amplitudes of the shortest wave lengths and gradually affects longer and longer wave lengths. At any time in the process there is one wave length whose reduction is contributing at a maximum rate to

change of the residual field. This wave length increases with successive applications of the operator. It is possible to associate this wave length with the number of passes of the operator over the field, or better with the parameter μ which is related to the number of passes.

In almost all cases there is one wave-length value at which the residual is changing more rapidly in terms of an RMS difference with changes of μ than at any other wave length. This simple maximum gives a measure of a characteristic scale of the map being processed. The characteristic scale is very stable from day to day. It is longer in winter than in summer and greater at the 500-mb level than at the earth's surface. If a characteristic scale of a map is found at μ_e this scale is reduced in amplitude to the 10% level by $1.5\mu_e$. Thus a cut at $1.5\mu_e$ may be taken to separate the characteristic scale of the map from the residual field.

This technique has provided an objective method for quantitatively separating individual features such as migrating cyclones (the SD chart) from the larger scale patterns. In attempting a simple forecast the migrating feature may be advected with a residual pattern or a "steering flow" derived in similar manner from this level and/or other levels. In examining the structure of perturbations of characteristic scale it is evident that they have a much clearer identity or more of a structure in the vertical than is apparent from the charts at the standard pressure levels. Closed highs and lows at the 500-mb level within the main stream of the westerlies are the rule rather than the exception. Perturbation charts at the 500-mb level resemble those at the surface, the intensities of the perturbations at the 500-mb level usually being the greater. The structures exhibit slopes toward cold air for lows and warm air for highs compatible with synoptic experience.

In the day-to-day analyses it is noted that movements of the disturbances are consistent from one map to the next and that features maintain intensity quite well with time. Where discrepancies appear between forecasts and analyses the scale separation may give a clue to the nature of errors of the forecasts. The separation gives a magnitude and a location to quantities very similar to those involved in synoptic reasoning. Usually no zonal component is present at sea level, the residual field denoting the current location and strength of the large-scale semipermanent features.

The residual field at the 500-mb level (the SR chart) has been of especial interest. Often it is possible to predict accurately the success of the 500-mb forecast for the next three days from the wave length and the intensities of the trough-ridge patterns displayed. These residual fields strongly indicate the prevailing storm tracks and change only slowly from day to day. To the extent that the changes are predictable, it is thus possible to anticipate changes in the storm tracks. To examine the features of this residual field further, it has been found helpful to subtract out the purely zonal component so that only the perturbations of the residual field remain (the SL chart). This procedure gives these quantities also shape, intensity, and location, so that they are completely specified numerically.

4. Surface Forecast - The surface forecast is carried out in two basic parts: one which is dynamic in character and the other which is empirical. The results of these two approaches are merged to obtain the final forecast.

a. Dynamic Surface Forecast. The dynamic model requires the surface analysis, 850-mb height and temperature analyses and the 500-mb D-value forecast at hourly intervals to 48 hours as inputs. From these are produced an hourly history tape of surface pressure fields from $\tau=0$ to $\tau=48$.

The prognostic equation used in the surface model is

$$p_{\tau+1} = p_\tau + \frac{g\,p_\tau}{R_d T}\,\Delta z_\tau^{1000}$$

where g is the acceleration due to gravity, R_d is the gas constant for dry air, p_τ is the surface pressure at time τ, T is the temperature and Δz_τ^{1000} is the height change of the 1000-mb level from τ to $\tau+1$.

The 1000-mb height change is assumed to be proportional to the 500-mb height change and to low-level temperature advection

$$\Delta z_{\tau}^{1000} = k_1 \Delta z_{\tau}^{500} + k_2 c \frac{\mathbb{V}_{\tau}^{500}}{2} \cdot \nabla \left(\mathbb{V}^{850} \cdot \nabla T^{850} \right)_{\tau=0}$$

where k_1 and k_2 are weighting coefficients, c is a conversion factor equal to 1200 cm/°C, Δz_{τ} is the time-centered 500-mb height change obtained from the upper air forecast, $\frac{\mathbb{V}_{\tau}^{500}}{2}$ is the advecting wind and $\left(\mathbb{V}^{850} \cdot \nabla T^{850} \right)_{\tau=0}$ is the initial low-level thermal advection. The coefficient k_1 is kept at 0.5 but k_2 varies according to the following scheme:

k_2 = 0.250 cold air advection over water
1.000 warm air advection over water
0.375 cold air advection over land
0.750 warm air advection over land

These coefficients are varied slightly with the season.

The 500-mb height change is taken directly from the 500-mb forecast model history tape using the following difference equation:

$$\Delta z_{\tau}^{500} = D_{\tau+1}^{500} - D_{\tau}^{500}$$

The advection field at 850 mb is moved with one-half the speed of the 500-mb wind field between time steps

$$A_{\tau+1} = A_{\tau} + \frac{\mathbb{V}_{\tau}^{500}}{2} \cdot \nabla A_{\tau}$$

The advection field $(\mathbb{V} \cdot \nabla T)_{850}$ is smoothed each 6 hours which weakens it to 5/6 of its initial value. Warm advection is not permitted if the initial temperature exceeds 16°C. The process is repeated until a 48-hour history tape containing forecasts for hourly time steps is complete.

b. <u>Empirical Surface Forecast</u>. Next the dynamic prediction is modified in the area of surface lows to agree with empirical computations made by computer. The field is searched for pressure minima of a certain depth. This depth is a function of latitude and season; in addition, certain continental areas are excluded because of the prevalence of heat lows in these regions. A minimum, average circulation strength of 15 knots is required for consideration.

Lows favorably located with respect to the current 500-mb flow patterns (that is ahead of troughs) are treated. Computations are made each 12 hours for 24 hours into the future using the surface and 500-mb history tapes. Amount of deepening is computed using the over-ocean methods from Joseph J. George's book, <u>Weather Forecasting for Aeronautics</u>.

A standard pressure profile with distance from the low center is assumed, and the results of these empirical computations are used to modify the dynamic computations hour by hour. Some smoothing is required to make the two forecasts mesh.

c. <u>Planned New Surface Model</u>. Changes in the dynamic model now being programmed include

(1) breaking the advection into two layers - sfc to 850 mb and 850 to 700 mb; defining the advection in terms of mean flow and thickness

(2) eliminating cold advection under actual terrain

(3) modifying low-level advection over ocean by heating.

Changes in the cyclone computation include

(1) using different computation methods in different geographic areas

(2) using individual storm histories

(3) adding cyclogenesis in two areas of naval interest

(4) using initial low shape plus rotation with movement.

5. Upper Air Forecast - The upper air forecast model used at FNWF is a one-layer modified barotropic model designed by Carstensen. It assumes conservation of potential vorticity

$$\frac{D}{Dt}\frac{(f+\zeta)}{h} = 0 \qquad (1)$$

where h is the thickness of a layer considered to be approximately the troposphere which is centered at the 500-mb level. Expanding equation (1) and multiplying through by h yields

$$\frac{\partial (f+\zeta)}{\partial t} - \frac{1}{h}(f+\zeta)\frac{\partial h}{\partial t} + \mathbb{V}\cdot\nabla f + \mathbb{V}\cdot\nabla\zeta - \frac{1}{h}(f+\zeta)\,\mathbb{V}\cdot\nabla h = 0 \qquad (2)$$

where f is earth's vorticity, ζ is relative vorticity and $\mathbb{V}$ is the horizontal velocity vector.

If the last term in (2) is further assumed to have three components, (a) a mountain term, (b) a latitudinal term, and (c) a temperature term, equation (2) may be written as

$$\frac{\partial (f+\zeta)}{\partial t} - \frac{1}{h}(f+\zeta)\frac{\partial h}{\partial t} + \mathbb{V}\cdot\nabla f + \mathbb{V}\cdot\nabla\zeta - \frac{1}{h}(f+\zeta)\mathbb{V}\cdot\nabla h_1 - \frac{1}{h}(f+\zeta)\mathbb{V}\cdot\nabla h_2$$

$$- \frac{1}{h}(f+\zeta)\mathbb{V}\cdot\nabla h_3 = 0 \qquad (3)$$

The second, fifth, sixth, and seventh terms are all relatively small, but they are included because they appear to improve forecast results. The second term, called the "Helmholtz" term, is a stabilizer. In the FNWF model, the approximation is made that

$$\frac{1}{h}(f+\zeta)\frac{\partial h}{\partial t} \approx \frac{\mu}{\bar{h}}\bar{f}\frac{\partial z}{\partial t} \tag{4}$$

where z is the height of the 500-mb surface, $\bar{f}$ is a mean value for $(f+\zeta)$, $\bar{h}$ is a mean value for h, and μ is a tuning constant determined by experience.

In the mountain term it is assumed that

$$\frac{1}{h}(f+\zeta)\mathbb{V}\cdot\nabla h_1 \approx -a\frac{f}{h}\mathbb{V}\cdot\nabla M \approx -\mathbb{V}\cdot\nabla\frac{afM}{\bar{h}} \tag{5}$$

where M is the smoothed terrain height and a is another tuning constant determined by experience.

The latitudinal term has the effect of decreasing the thickness of a layer of air moving south and increasing the thickness of a column with a northward component. If one assumes this effect to be a function of latitude only, it may be combined with the advection of earth's vorticity to give

$$\mathbb{V}\cdot\nabla f - \frac{1}{h}(f+\zeta)\mathbb{V}\cdot\nabla h_2 \approx \mathbb{V}\cdot\nabla f^* \tag{6}$$

where f^* is taken not as $2\omega\sin\phi$ but as $2w\left(\frac{1+\sin\phi}{2}\right)^2$.

The temperature term is based upon the assumption that vertical stretching of the mid-troposphere normally occurs where advection is bringing in a colder troposphere. Here the approximation is made that

$$\frac{1}{h}(f+\zeta)\mathbb{V}\cdot\nabla h_3 \approx \frac{b\bar{f}}{\bar{h}}\mathbb{V}\cdot\nabla H \approx \mathbb{V}\cdot\nabla\frac{b\bar{f}H}{\bar{h}} \tag{7}$$

where b is a tuning constant and H is the thickness of the 1000-500-mb layer.

Collecting terms and substituting gives the final basic forecast equation

$$\frac{\partial}{\partial t}\left(\zeta - \frac{\mu \bar{f}}{h} z\right) = -\mathbb{V}\cdot\nabla\left(f^{*} + f + \zeta + a f M - \frac{b \bar{f} H}{\bar{h}}\right) \qquad (8)$$

The forecast produced with the aid of equation (8) is carried out on a 63×63 grid in which the equator is an inscribed circle; however, those grid points south of 2N are excluded from computations.

Several additional assumptions and/or operations are introduced for practical reasons in applying equation (8) to routine operations:

a. The wind used in the advection process is like a geostrophic wind determined over a 2-mesh length interval except that $\sin\phi$ is replaced by

$$\frac{9}{16}\left(\frac{1+\sin\phi}{2}\right)^2 + \frac{7}{16}\sin\phi \ .$$

The exact values of $\frac{9}{16}$ and $\frac{7}{16}$ were selected for convenience in the program. This approximation avoids many practical difficulties near the equator.

b. Some slight smoothing is introduced and also the ellipticity criterion is imposed at six-hour intervals throughout the forecast. The time step is non-centered following this operation, but centered at all other hours.

c. The thickness is carried forward during the forecast as an independent field with half of the speed of the 500-mb winds.

d. To reduce its truncation error, the advection term is multiplied by a factor which is always equal to or greater than one. This factor exceeds unity by the largest amount where the curvatures of the two fields of interest are largest.

B. OCEANOGRAPHY (Basic)

1. Sea Surface Temperature - The present Sea Surface Temperature (SST) analysis program utilizes a mesh length one-half of standard (approximately 100 nautical miles), and a median instead of a fitted value is determined for each grid point. Ship injection temperatures collected over a period of 24 hours are compared with previously analyzed values at the nearest grid point. If a new observation is warmer than the previous analysis, the value at the grid point is raised a fixed amount (currently 0.2F); similarly, if the observation is colder, the value is lowered the same amount.

The data handling is such that the most recent report within one-half mesh length of a grid point gets the final 'vote.' Areas which receive no new data are modified only by relaxation and smoothing. This median-seeking method was selected in order to reduce the influence of the errors known to be common in ship injection temperature observations.

2. Wind Wave - The analysis and forecast program for wind waves utilizes the methods of Sverdrup, Munk, and Bretschneider (SMB) to obtain significant wave height and period. A history tape of surface geostrophic winds at three-hourly intervals from 24 hours in the past to 30 hours in the future is the basic input. Heights and periods are computed at 0, 12, 24, and 30 hours as a function of wind speed, duration and fetch. Duration is determined to the nearest three hours; a wind shift of greater than 22 degrees is assumed to terminate growth at any grid point.

The SMB curves for growth of wind waves as a function of duration D_f and geostrophic wind speed U_g have been approximated by expressions of the following form:

$$H_{1/3} = a\left(U_g\right)^2 D_f + bU_g$$

$$T_{1/3} = \left(c + dD_f\right)U_g + e$$

where a, b, c, and d are constants. For practical reasons, the maximum allowable geostrophic wind is 25 meters per second; this limits the maximum $H_{1/3}$ to 40 feet.

Corrections for fetch are made if land is found one (short fetch) or two (long fetch) grid intervals upwind.

3. <u>Swell</u> - The swell analysis and 30-hour forecast is based upon a history tape of wind wave heights and periods (from the program described above) at 12-hourly intervals from 84 hours in the past to 30 hours in the future. Travel distance, swell height and swell period are computed from the following equations for all wind waves with a height greater than four feet.

$$D = a_1 T_f \bar{m} t$$

$$T_D = \left(T_f^2 + \frac{b_1 D}{\bar{m}}\right)^{1/2}$$

$$H_D = H_f \left(\frac{T_D}{T_f}\right)^{-2.65}$$

where D is travel distance, T_f is the period at the end of fetch, $\bar{m}$ is the mean map factor along the decay path, t the decay time, T_D the swell period at end of decay, H_D the swell height at end of decay, H_f the height at end of fetch, and a_1 and b_1 are constants.

Swell is assumed to spread 15 degrees to either side of the principal decay direction and to move through a calm wind field. All grid points within one-half mesh length of the centerline are searched for land which would prevent a swell train from reaching the computed end point. This method will handle only what may be called the predominant swell height and period and only the highest swell reaching a grid point at the specified output times is retained because of computer storage limitations.

The programs described here are a fast computer application of the well-known methods of Sverdrup, Munk, and Bretschneider. The justifications for the approximations used are that they yield hemispheric sea and swell forecasts which are close to the values reported by the ocean station vessels and provide a product useful to naval operations, yet require a total running time of only five minutes.

4. Layer Depth - For operating areas where the number of BT observations is sufficient (Hawaii and San Diego OPAREAS at present), the mixed layer depth, average temperature of the mixed layer, depth of the thermocline and temperature at that depth are extracted from the observations and analyzed over a 20-mile grid system. Forecast changes to these initial analyses are made using Laevastu's heat balance model. The 48-hour change in layer depth and temperature is dependent upon hours of sunshine, cloud cover, wind speed, air-sea temperature difference and relative humidity.

C. DERIVATIONS

Several valuable byproducts are derived from the basic meteorological programs described above. The most important of these will be covered in the following paragraphs of this section.

1. Vertical Velocity - The vertical velocity at the surface of the earth, 850-, 700-, 500-, and 300-mb levels, is calculated by means of a diagnostic ω-equation

$$\nabla^2 (\sigma\omega) + \frac{p f \eta}{R} \frac{\partial^2 \omega}{\partial p^2} = \nabla^2 \left[\frac{g}{f} J(D, T) \right] - J(T, \eta) - J\left(D, \frac{g}{f} \nabla^2 T\right)$$

from data of the 1000-, 850-, 700-, 500-, and 300-mb analyses and forecasts prepared by this activity. The input data consists of the height of these surfaces and a temperature calculated to provide hydrostatic consistency in the vertical.

The upper boundary condition for the three-dimensional numerical solution of the 8000 equations involved is that vertical velocity = 0 at 100 mbs. The lower boundary condition is calculated in detail; terrain forced vertical motion and frictionally induced vertical motion are combined to give a net vertical motion which is applied at the surface of the earth. Vertical motions are not calculated "inside" terrain whereever constant pressure surfaces lie below the earth's surface. The vertical motions are initially calculated in mbs/sec and are then converted to cm/sec by using the actual density.

The operational output is presented through charts of vertical motion w in cm/sec. Up motion is contoured at intervals of 2 cm/sec. Down motion is not contoured. All significant centers of motion are marked and labeled with the central value in tenths of cm/sec. Areas of a chart that are "inside" the terrain are delineated with a dashed line and vertical motion values within these areas are to be disregarded; values given are fictitious and are the result of the machine drawing of the chart.

The vertical motions presented at the 850- and 500-mb levels in a sense represent the lower troposphere and high troposphere respectively and are a useful interpretation in utilizing this data. It is to be noted that the surface boundary motion decays exponentially with height and the influence on the 850-mb motion (or other levels) varies accordingly. The release of latent heat in saturated rising air will be added to the computation in the future, and the values of ascending vertical velocities will increase markedly at that time.

The vertical velocities are very sensitive to inconsistencies in the analyses of the height and temperature fields and occasionally concentrated, unreal and extremely large values (bull's eyes) may arise due to a poor datum. Vertical velocities associated with tropical cyclones in sparse data areas are not representative due to the method of analysis.

Vertical velocities are calculated twice daily at 00Z and 12Z. The analysis is ready for transmission in plus 10 hours and the 36-hour forecast in plus 13 hours.

2. <u>Hurricane and Typhoon Trajectories</u> - From the observation time at which the 500-mb forecast originates, steering trajectories through 72 hours are developed and issued to Navy forecasters in both the Atlantic and Pacific Oceans as an aid in determining a tropical cyclone's future track.

Four steps are completed for each hourly steering computation as follows:

a. The relative vorticity is removed from an area of 16 or 24 grid points surrounding the storm center by setting $\nabla^2 D = 0$.

b. Using the coefficient of the space mean program, two smoothing passes are made.

c. The "u" and "v" components of the wind are determined at sixteen grid points surrounding each of the five points.

d. Using the Newton-Bessel double quadratic interpolation formula, values of "u" and "v" at the center and four surrounding points are obtained.

Before a final message is outputted, the mean of the five points is computed. This mean is used as the "best" position in most forecast messages. For activities desiring to see the forecast positions of all five points, a message is prepared in the following format:

HURRICANE AND TYPHOON STEERING MESSAGE

12Z 08 TYPHOON GLORIA FROM YOUR 09/0 122Z

HOUR	0		6		12		18	
POINT	I	J	I	J	I	J	I	J
CENTER	XXX	XXX	XXX	XXX	211	497	214	501
NORTH	XXX	XXX	XXX	XXX	216	489	222	494
EAST	XXX	XXX	XXX	XXX	202	492	205	496
SOUTH	XXX	XXX	XXX	XXX	205	506	206	508
WEST	XXX	XXX	XXX	XXX	220	502	224	505

HOUR	24		36		48		72	
POINT	I	J	I	J	I	J	I	J
CENTER	215	502	212	498	216	489	229	472
NORTH	224	498	225	500	228	496	239	488
EAST	204	497	201	489	208	477	223	453
SOUTH	203	507	197	496	203	482	220	456
WEST	226	507	226	506	229	501	237	493

NNN

NNN - "I" and"J" grid-point values in tens and tenths

D. MESSAGES

For those naval activities which are not yet in the Naval Weather Service Computer Network, it has been necessary to disseminate products by addressed message. A sample of each message format and a brief explanation follow; the abbreviated program title used at FNWF is given at the start of each example.

WAVE ANAL AND FCST MSG

UNCLAS

ATLANTIC 30 HOUR SEA AND SWELL FORECAST FROM 161800Z

90478 04102 02084 90480 04112 04357 90482 03102 02054

90484 03082 03054 90538 04092 03073 90540 04102 06083

$9NNNN \quad H_w H_w D_w D_w P_w \quad H_s H_s D_s D_s P_s$

9	-	group identifier
NNNN	-	grid point number
$H_w H_w$	-	height of significant wind wave in feet
$D_w D_w$	-	direction from which wind waves are coming in tens of degrees true
P_w	-	period of significant wing waves. Coded value times two equals number of seconds, 0 code equals 20 seconds
$H_s H_s$	-	height of swell in feet
$D_s D_s$	-	direction from which swell are coming in tens of degrees true
P_s	-	period of swell. Coded value times two equals number of seconds, 0 code equals 20 seconds

Wave data is compacted into message format. Values of sea and swell height and period at selected grid points for analyses and 30-hour forecast times are included in message.

HEAPS

UNCLAS

FNWF HEAPS MLD FCST VALID 48 HR FROM 00Z 06 NOV 63

77202 77202 77202 77202 77202 77202 77202 77202 77202 77202

77192 79192 79192 79192 79202 79202 77202 77202 77202 77202

79172 79172 79172 78182 79192 79202 79202 77202 77202 77202

79152 81142 79142 79162 79172 79192 79202 77202 77202 77202

TTZZS

TT - temperature of sea surface in °F

ZZ - mixed layer depth in tens of feet

S - sea state

Sea surface temperature, mixed layer depth and sea state for certain grid points within Hawaiian area are reported by above message format. Location of grid points is given by an initial instruction issued upon request.

SOCAL

UNCLAS

FNWF SOCAL MLD FCST VALID 48 HR FROM 00Z 17 MAR 64

59134 61104 61094 61094 61084 61084 61074 61074 61074

59104 61114 61144 61134 61104 61084 61084 61074 61084

TTZZS

Message format explained below sample HEAPS message.

Southern California area sea surface temperature, mixed layer depth and sea state are depicted in above message. Grid-point locations are promulgated by separate instruction.

MLD MSG

UNCLAS

FNWF SEA FCST VALID 30 HR FROM 18Z 16 MAR 64 EAST PAC

91091 07022 02316 5917X 91153 08043 02316 6019X

91154 05042 03003 5814X 91215 04062 05005 5915X

9NNNN $H_wH_wD_wD_wP_w$ $H_sH_sD_sD_sP_s$ TTZZX

9	-	group identifier
NNNN	-	grid point number
H_wH_w	-	height of significant wind wave (feet)
D_wD_w	-	direction from which wind waves are coming (tens of degrees true)
P_w	-	period of significant wind waves. Coded value times two equals number of seconds. 0 code equals 20 seconds
H_sH_s	-	height of swell in feet
D_sD_s	-	direction from which swell are coming (in tens of degrees true)
P_s	-	period of swell. Coded same as P_w
TT	-	temperature in °F at the mixed layer
ZZ	-	depth of the mixed layer in tens of feet

Height and direction from which wind waves are approaching; period of significant wind waves; height and direction from which swell is approaching; period of swell; temperature in the mixed layer and depth of mixed layer are extracted and computed from sea and swell 30-hour forecast fields.

AVERAGE SURFACE WINDS

UNCLAS Y

1000 MB WIND VECTORS FOR WEEK ENDING 101200Z

08000 15005 08020 06010 18060 29031 28080 29026 28060 26022

28040 24019 28020 24019 28000 23024 38080 21031 38060 16027

$QL_aL_aL_oL_o$ DDVVV

Q - octant of globe

L_aL_a - latitude in degrees

L_oL_o - longitude in degrees

DD - wind direction in tens of degrees

VVV - wind speed

Wind components for fourteen 0000Z and 1200Z surface analyses are weighted and then combined into speed and direction for weekly transmission to the Oceanographic Office for use in ice forecasting.

ISOTACH FCST MSG

UNCLAS

500 MB FORECAST HEIGHTS AND WINDS FROM 161200Z

08500 50624 04124 48826 04948 48632 05772

18590 48714 02924 47716 00848 48623 04672

$QL_aL_aL_oL_o$ HHHDD VVVtt

Q - octant of globe

L_aL_a - latitude in degrees

L_oL_o - longitude in degrees

HHH - heights in meters

DD - wind direction in tens of degrees

VVV - wind speed in knots

tt - forecast time; 24, 48 and 72 hour categories only

500 mb 24-, 48-, and 72-hour forecast heights and winds for selected points of latitude and longitude are extracted from data fields and placed in the above message format.

FIVE - THREE (5 - 3)

UNCLAS

500 MB AND 300 MB FCST WINDS FM 170000Z

07500 24056 24076 07520 25046 25069 07540 25049 24075

07560 22052 22080 07580 26029 25039 17500 29039 29055

$QL_aL_aL_oL_o$ DDVVV

Q -	octant of globe
L_aL_a -	latitude in whole degrees
L_oL_o -	longitude in whole degrees
DD -	wind direction in tens of degrees
VVV -	wind speed in knots

Twenty-four-hour forecast wind direction and speed at selected points of latitude and longitude are combined to make up the Five - Three (5 - 3) Message.

7-5-3-2 ANALYSIS AND FORECAST MESSAGE

UNCLAS

AUPA-1 PEARL 7/5/3/2 ANALYSIS FROM 161200Z

08500 70328 02670 51630 03850 86031 05130 11432 05420

18590 59118 01870 49918 04150 83919 06230 09719 05820

28580 51912 01270 48412 02050 81612 02930 07113 03320

$QL_aL_aL_oL_o$ HHHDD VVVPP

L_aL_a/L_oL_o	-	in whole degrees
HHH	-	in whole meters omitting first figure at 700, 500 and 300 and tens of meters omitting first figure at 200 mb
DD	-	in tens of degrees
VVV	-	in whole knots
PP	-	pressure level in decibars

Initial 2 or 3 omitted in message code for 700 mb.

Initial 4 or 5 omitted in message code for 500 mb.

Initial 8 or 9 omitted in message code for 300 mb.

Initial 1 and final zero omitted in message code for 200 mb.

Analysis and 12-, 24-, and 36-hour forecast heights, wind direction and velocity at 700, 500, 300 and 200 mbs at selected points of latitude/longitude are extracted from applicable height and wind fields and combined into above message format.

WIND MSG

UNCLAS

FUSJ 52 FNWF

HHHHDDVVV FOR 1000-850-700-500-400 MB COMPUTED ON GWC EDPS GRID. FORECASTS VALID 24 HRS AFTER 0000Z 17 03 64

1018	-03122015	-11722012	-21523008	-37731003	-47900006
1017	-01902002	-11505005	-22406009	-40506016	-51906020
1016	-03904015	-14104014	-26005014	-45407013	-57608014
1015	-08306033	-17706022	-28606010	-46622011	-57923023

NNNN HHHHDDVVV

NNNN - grid point number

HHHH - "D" value in meters; positive or negative value indicated by "0" or "-"

DD - wind direction in tens of degrees

VVV - wind speed in knots

The Wind Message contains twenty-four- and thirty-six-hour forecast of heights, represented by "D" values, and winds at mandatory levels, 1000 mbs through 400 mbs, respectively.

STRATO-ANAL WINDS

and

24 HR STRATO FCST WINDS

ANALYSIS WINDS 12Z 16 MAR 64

92174 35026 00035 01041 02047 02050 02047 02046 01049 16066 16170
17275 17210 17159 18111 20063 25034 31052 33089 34130 34172 34214
92112 29019 31032 33038 34048 35057 35065 36068 35069 35067 35064

9NNNN DDVVV

9NNNN - grid point identifier (9) and four digit grid point
DDVVV - direction in tens of degrees and speed in knots

Speed and direction of winds from the surface to 100,000 feet in 5000-foot increments are extracted from derived wind analyses and forecast fields.

RADFO

UNCLAS

RADFO01 PACIFIC FALLOUT FORECAST 24 HRS FROM 00Z 17 MAR 64
17006

12327 23621 43523 12723 23639 23645 13018 20246 40252
12631 20310 20211 13127 20121 40124 13523 20424 20429

Effective Fallout Winds Messages are in format of RADFO Messages in OPNAV Instruction P3444.3A except that the fallout wind has been substituted for the trajectory and that speed in knots has been substituted for length of trajectory.

CYCLONE

UNCLAS

CYCLONE FORECAST

POSIT 161200Z 12HOUR FCST.24HOUR FCST.36HOUR FCST.48 HOUR FCST.
451 916W012 494 851W008 537 786W004 554 801W006 554 814W009
477 526W983 494 506W974 510 485W965 513 484W968 490 430W970

12-, 24-, 36-, and 48-hour forecast positions of latitude, longitude and central pressure for Northern Hemisphere cyclones above 25° latitude are transmitted. Self-explanatory format appears above.

HAT ZONAL WINDS

500-MB ZONAL WINDS

FORECAST VALID 12 HRS AFTER 1200Z 16 03 64

HEMISPHERIC			-00510	000615	001920	003025	003730
004135	004040	003245	001550	000855	001960	002865	002570
LONGITUDE 020W-120W			-00710	000215	001620	002925	003930

$dfffL_aL_a$

d	-	direction	- =	East
			0 =	West
fff	-	zonal component in knots		
L_aL_a	-	beginning of 5° latitude band in whole degrees		
				12-1/2° - 72-1/2°

To compute the HAT Zonal Winds the following steps are taken:

a. Average the "D" values for 5° latitude bands for four sectors and the hemisphere.

b. Find the average latitude of grid points within the 5° latitude band.

c. Perform an unequal Lagrangian interpolation to find "D" value at start of 5° latitude band from 10° N to 75° N.

d. Compute geostrophic zonal wind values at mid-point of each latitude band for each sector and hemisphere.

LONG WAVES

UNCLAS

LONG	WAVES	01700					
00585	57856	35495	45539	01586	57856	05455	40535
02587	57555	45375	34529	03587	57755	35325	29523

$L_o L_o$HHH HHHH

$L_o L_o$ - Longitude in tens of degrees for ten degree intervals Range $0^\circ - 350^\circ$

HHH - Height in tens of meters, ranging from 20° latitude to 70° latitude along a line of longitude

Selected heights around latitude circles from long-wave analyses and forecast are transmitted, providing a simplified large-scale forecast.

HI-LO

500 MBS HIGH/LOW CENTERS 00Z 17 MAR 64

00HR VT 00170364

HI	+312	17.2N	056.7W	HI	+312	22.0N	057.3W
LO	+300	21.5N	049.3W	HI	+307	24.4N	044.2W

Forecast height values and position of major hemispheric 500-mb High/Low Centers are extracted from 500-mb analysis and forecast fields for the following time intervals: 0, 12, 24, 36, 48, and 72 hours. Reference date-time of barotropic forecast appears in title.

V. PLANNED PROGRAMS

A. METEOROLOGY

The following meteorological programs are now active (A) or are scheduled for attack (P) in the near future:

1. New surface analysis (A).
2. New surface forecast (A).
3. Tropical analysis and forecast (A).
4. Southern Hemisphere analysis (P).
5. Hourly terminal forecast (A).
6. Tropical storm formation (A).
7. Cloud and precipitation forecasts (A).
8. Computer climatology (P).
9. Freezing level forecast (A).
10. Vapor trail forecast (P).
11. Baroclinic forecast (P).

B. OCEANOGRAPHY

The following oceanographic programs are now under active development (A) or in the planning stage (P):

1. Revised sea and swell analysis and forecast (A).
2. Analysis of temperature at selected depths (A).
3. Forecast of layer depth from mechanical mixing and heat budget considerations (A).
4. Computer climatology of sea conditions (P).
5. Surface current analysis (P).

C. OPCON FILES

Plans are well along for three types of meteorological and oceanographic files for input to Operations Control Centers:

1. Synoptic analyses and forecasts of parameters at grid points.
2. Climatological fields of parameters at grid points.
3. "Spot" files of synoptic and climatic information for selected stations or locations.

The initial list of parameters which will be made available for OPCON Center use is

1. Oceanographic data.
   a. Sea Temperature.
   b. Mixed Layer Depth.
   c. Wind Wave Heights.
   d. Wind Wave Directions.
   e. Wind Wave Periods.
   f. Swell Heights.
   g. Swell Directions.
   h. Swell Periods.
   i. Combined Heights.
   j. Combined Directions
   k. Combined Periods.
2. Atmospheric data (sea-level surface).
   a. Temperature.
   b. Dew-point Temperature.
   c. Visibility.
   d. Clouds:
      (1) Low Clouds.
      (2) Middle Clouds.
      (3) High Clouds.
   e. Precipitation.
   f. Pressure
3. Atmospheric data (upper air).
   a. Temperature.
   b. Dew-point Temperature.
   c. D-values.
   d. Vertical Motion.
   e. Disturbance Field.
   f. Residual (Long Wave) Field.
   g. Long-wave Disturbance Field.

VI. COMPUTER NETWORK

The Naval Weather Service is preparing an official plan for incorporating computers into the Weather Central System. The computer capabilities called for in this plan fall into four broad categories with basic support functions as follows:

Master Computer Center (Monterey)

Global Analysis and Forecasting
Global Climatology
Research
Planning
Personnel Training
Equipment Procurement
High-Speed Communication Development

Major Computer Centers (Pearl, Guam, Norfolk, Rota)

Fleet Support
ASWEPS Support
Polaris Ballistic Computation
OPCON Center Support
Regional Data Collection and Editing

Minor Computer Centers (Suitland, Sangley)

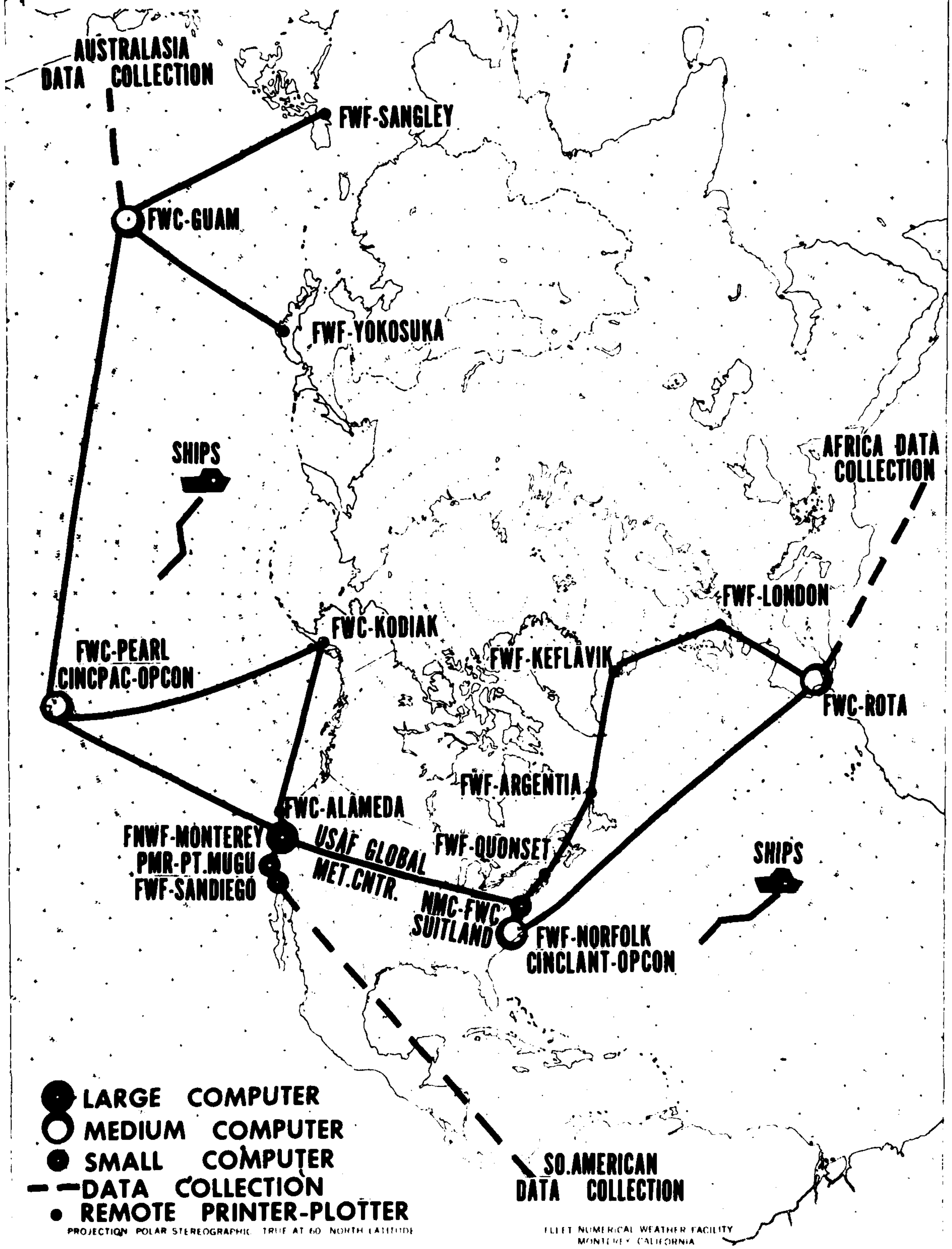
Fleet Support
Regional Data Collection and Editing (Sangley)
Data Exchange with National Meteorological Center (Suitland)

Remote Units (all other FWC/FWF)

Note: These units will have a printer/plotter installation capable of receiving numerical products from the nearest major center and will contribute raw data to the master center through the major centers' high-speed communications link.

High-speed data links (4000 words per minute) now connect Monterey, Suitland, Norfolk, Alameda, Point Mugu, and Pearl Harbor. A CDC-160A computer has been installed at FWC, Guam and a new high-speed link should be activated between Hawaii and Guam in June 1964. The computer network as planned for 1968 is shown on the following chart.

NAVAL WEATHER SERVICE COMPUTER NETWORK - 1 JULY 68



A. NETWORK

1. Communications

a. The major part of the dissemination of numerical products is accomplished over computer to computer cable links at a rate somewhat greater than 4000 teletype words per minute. All of the data transmitted by this mode is considered completely error free. All other dissemination of the products is accomplished over normal Navy communication facilities.

b. Collection of raw data for use in generating the numerical weather products is done via the dissemination links plus eight incoming weather teletype circuits at FNWF.

c. While hard wire circuits supply the means for transmission for most of the existing networks, it is obvious that high-speed radio data links will be necessary to expand the network so that full utilization of numerical products can be realized. To this end computer to computer RF data transmission feasibility tests were conducted in 1962 (and development tests in early 1963) between Washington, D.C., and Monterey. Currently computer-to-computer tests are being conducted between FWC, Pearl and FNWF, Monterey utilizing newly developed commercial multiplexing equipment in conjunction with naval communications radio transmitters and receivers. Average error-free data transmission rates of 2000 to 4000 teletype words per minute have been achieved. The major deterrent to operational use of this system is the lack of adequate circuit control. Full support in this area coupled with greater priority would allow operational usage of this transmission mode to remote small field computer locations and possibly even to ships.

2. Existing Network

a. Monterey - PMR Computer Link. This link has been changed to a full-time circuit leased by the Pacific Missile Range. Transmission of charts to PMR has been routine. It is planned to transmit clean data summaries for the PMR area of interest.

b. Monterey - Suitland Computer Link. The load on this link has increased greatly since the last report and traffic now occupies sixteen hours per day. Relay of numerical products to the eastern Atlantic and Europe is via this link.

c. Monterey - Pearl Harbor Computer Link. This link became operational on 1 October 1963 with installation of a CDC-160A and associated communication equipment at FWC, Pearl Harbor. Traffic already amounts to 78 charts plus special messages per day. Relay of messages and grid charts to WESTPAC users is via this link.

d. Remote Plotters. Remote plotters have been installed at FWC, Alameda; FWF, Norfolk and at the Norfolk OPCON Center. Norfolk products can be sent direct from Monterey or can be relayed by Suitland.

e. Transmission link components are shown on Chart AA.

3. Planned Network

a. FWC, Guam Computer. A CDC-160A computer and associated equipment have been installed at FWC, Guam. Traffic from Hawaii to Guam will not become heavy until after June 1964, when a new cable becomes available; RF tests will be carried out using LENKURT gear being installed at Guam and Pearl Harbor.

b. Monterey - Pearl - Kunia Link. The cable from Monterey to Pearl has recently been extended to the OPCON Center at Kunia. A switching arrangement makes it possible for Monterey to transmit directly to Kunia or relay through FWC, Pearl. The Kunia installation began receiving FNWF products on a test basis in April 1964.

B. EQUIPMENT (Small Field Installations)

1. Existing equipment at small field installations is shown on Chart BB. It should be noted that many of the components shown have been designed and built at FNWF. These include:

a. TRAP - Data line - computer interface and plotter control.

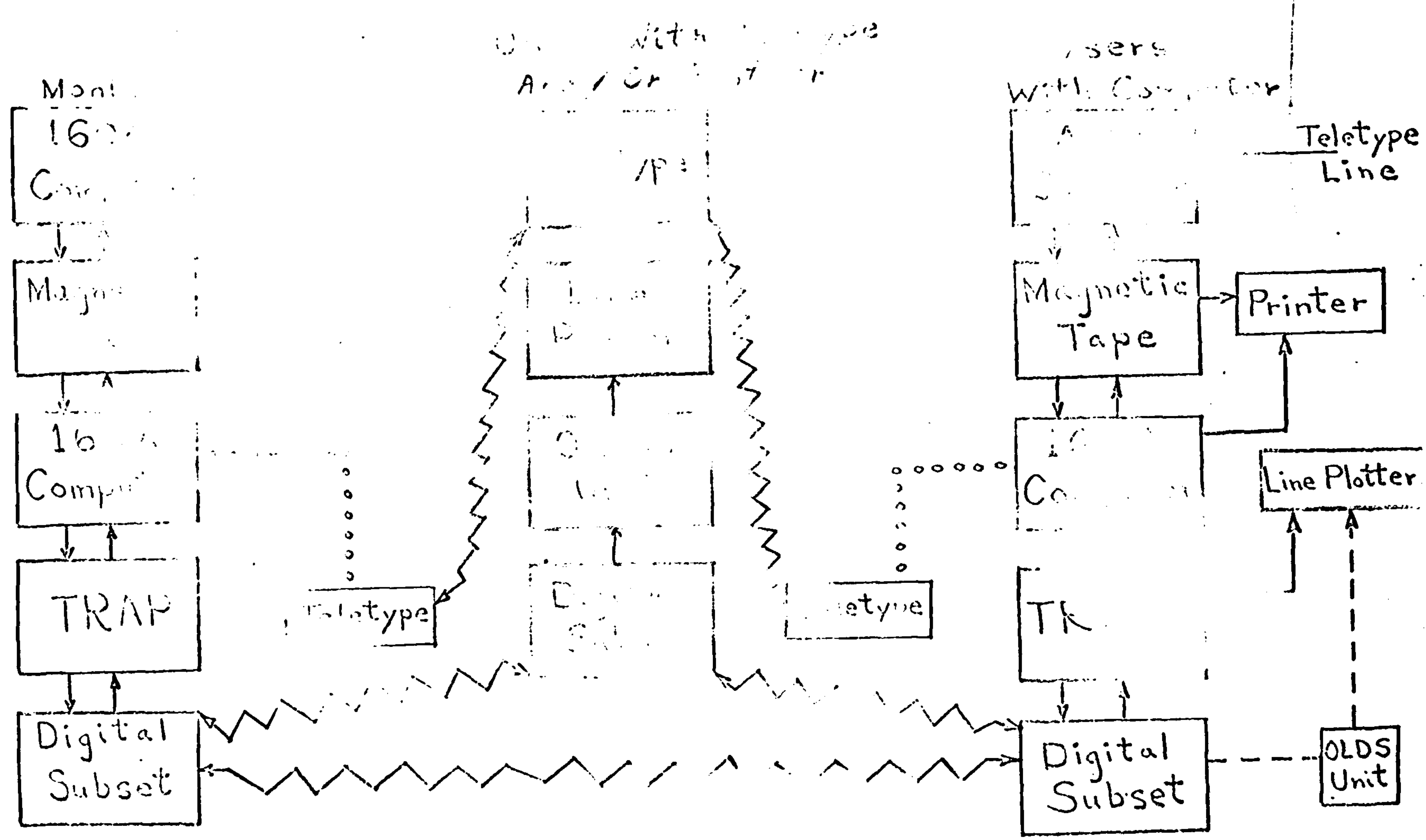
b. OLDS - Data line - plotter interface.

c. OSCAR - Multi option - selector.

(NEW EQUIPMENT NOW IN OPERATION)

d. Auto-Collector. Seven Auto-Collectors have been built for use on circuits at Monterey. The Auto-Collector utilizes

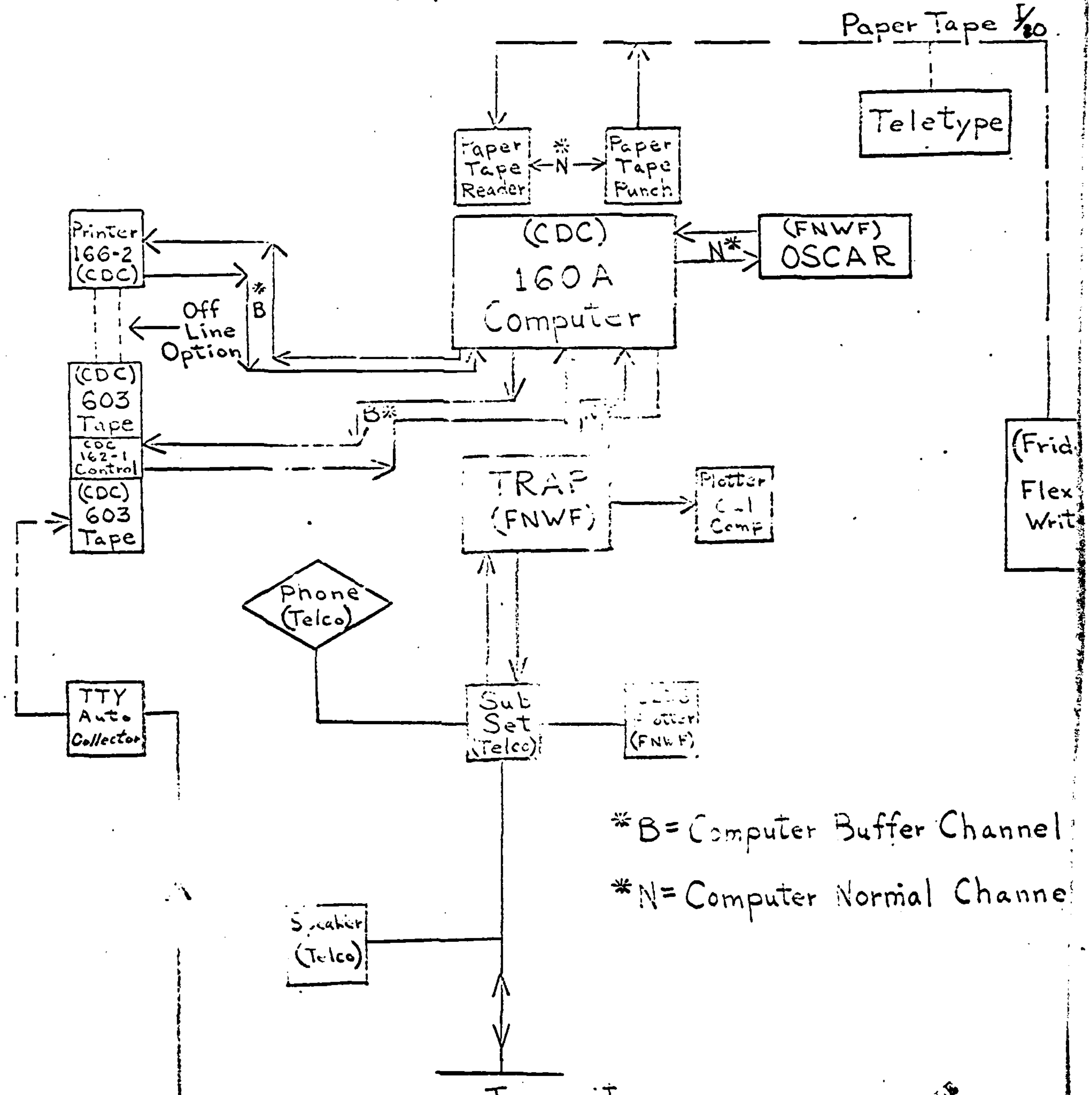
Communications Link Components



.... Paper Tape
VVV Transmission Circuits

TRAP: Transmission, Receive And Plot Unit
OLDS: On Line Display System

Equipment Schematic



*B = Computer Buffer Channel

*N = Computer Normal Channe

Receive only teletype data for processing and transmission to FNWF Monterey an incremental magnetic tape transport to record incoming data directly on magnetic tape. The units are built "in-house" for \$10,000 each and are designed to accept data from 75 wpm, 100 wpm, 857 wpm, 1000 or 2000 bits/sec lines. Additional units are being built for Monterey as well as Pearl Harbor and Suitland.

e. Auto-Plotter. An Auto-Plotter has been built for Monterey at a cost of \$15,000. This is an off-line plotting system which uses an incremental magnetic tape transport to play back map-plot tapes generated on the 160A computer.

f. Switching Panel. A switching panel has been placed in operation which permits any of the three 160A computers at FNWF to be connected to any of the peripheral equipment. The switching is manual and greatly increases the versatility of the small-scale computers.

2. Planned Equipment

a. New peripheral computer equipment and communication devices now under development or investigation include:

(1) Remote Printer. To operate with OLDS III and remote plotter at sites which do not have a computer.

(2) Mag Tape to Mag Tape System. To augment the computer to computer transmission system. Data will be transmitted tape to tape when the CDC-160A computers are tied up on another task.

(3) Disk Storage. The development of a low-cost storage device for the CDC-160A is being investigated.

(4) Multiple Transmission. It is planned to develop a capability to transmit data to three computer units simultaneously. Computer programs are available. Development of subsets by the Telephone Company is in progress.

(5) Automated Transmission Relay. Automated relay through one computer to a second further from Monterey is being investigated.

(6) Breakpoint. A breakpoint unit to be used in checkout of 160A programs is being developed. It can also be used as a Selective Stop Switch for greater program control.

C. DATA HANDLING PROGRAMS (160A)

1. Transmission

a. Operational programs for the 160A are primarily for data transformation, transmission and peripheral equipment control for display purposes.

(1) Transmission: In order that the weather products of the 1604 computer may be used by weather activities on a real time basis, rapid electronic transmission and display become almost as important as production itself. In conjunction with the development of the computer equipment network (described previously) two transmission programs have been developed:

(a) Computer to Computer. This program controls the input (from external equipment) of information into the transmitting computer in packed format. It then controls the transmission of this information in optimum blocks - computing and sending a check at the end of each block. A portion of the program at the other terminal receives the information and computes a block check which is compared with the transmitted check. A receipt signal is returned and a new block is sent or the last block is retransmitted depending upon the returned signal. If a good signal is sent, the receive portion of the program controls the output to the desired external equipment. Features of this program include:

- Input from Magtape or Paper Tape Reader
- Output to Magtape, Printer, or Paper Tape Punch
- Binary or BCD format
- Variable length record Blocks (up to 4000_{10} 160A words)
- Multiple record input and output
- Multiple station transmission (up to 6 receivers)
- Wireline or radio channel transmission.

(b) Computer to remote line plotter (OLDS). For those installations which do not have a computer but have a requirement for numerical weather charts, an equipment display system program has been developed which allows the transmitting computer to control a line plotter at a remote site. The computer inputs (from Magtape) information that has been generated on the 1604 converts this information to plotter commands and uses these commands for remote plotting. Using the automatic answering feature of the modern telephone system it is unnecessary for the remote display site to be attended at the time of transmission. Features of the system include

- Automatic alignment of the remote plotter
- Automatic recovery from transmission errors
- Local, or remote plotting
- Extraction of a portion of a hemispheric chart
- Scaling (1:30 m or 1:60 m)
- Magtape generation of charts for AMP (Auto-Plotter) unit.

2. Transformation

a. A complete library of transformation programs has been developed. These programs allow for maximum flexibility in data handling and transformation such as

(1) Duplication of magnetic tapes.

(2) Transformation of raw data in teletype paper tape or auto-collector format into standard magnetic tape in record length and format readily acceptable to the 1604 ADP program. Redundancy editing is performed during transformation.

(3) Transformation to and/or from:

(a) Magtape.

(b) Cards.

(c) Paper tape teletype or flexowriter format.

(4) Extraction of area and/or points from the hemispheric product for specific users.

(5) Compilation of 1604-generated products to form new customized products for specific users.

3. Display

a. The primary display program is the plotter program outlined above; it can be used "in-house" to produce weather charts.

Other programs use the plotter to display such items as cyclone tracks, zonal wind profiles, and alphanumeric data. In every case, the data being displayed has initially been generated by the 1604.

b. Alphanumeric data display is normally accomplished on the 1612 printer (166 ~~printer~~ at field sites). Most of the 160A programs have incorporated the option of displaying the data on a printer.

VII. CHARTS

Most of the charts produced at FNWF, Monterey have been shown in previous progress reports. The following examples are presented to give a summary of the various types now available. The pattern separation and Sigma or stability charts are new developments which have not been included in earlier reports.

A. SFC PRES ANAL. See Chapter IV, Section A.1. (pp 13). Contoured at 8-millibar intervals. Produced every six hours.

B. SFC PRES 36 HR PROG. See Chapter IV, Section A.4. (pp 20). Produced every twelve hours. Ropresents a dynamic model modified by empirical cyclone track forecast.

C. CYCLONE FORECAST. See Chapter IV, Section A.4. (pp 20). Produced every twelve hours. Uses history from the 00Z and 06Z surface analyses (or 12Z and 18Z). Forecast central pressures in whole millibars truncated above 999.

D. SEA T ANAL. See Chapter IV, Section B.1. (pp 26). Contoured at 5°F intervals. Produced every twelve hours. Continental isotherms are not realistic but are used for establishing shoreline departures of marine isotherms.

E. 500 HT ANAL. See Chapter IV, Section A.2. (pp 15). Contoured at 60-meter intervals. Temperatures contoured at 5°C intervals.

F. 500 HT 48 HR PROG. See Chapter IV, Section A.3. (pp 18).

G. 500 SD ANAL. See Chapter IV, Section A.3. (pp 18). 500-mb short wave disturbance analysis contoured at 30-meter intervals.

H. 500 SR ANAL. 500-mb residual or long wave pattern contoured at 60-meter intervals.

I. 500 SL ANAL. 500-mb long wave disturbance analysis obtained by subtracting the zonal component from the SR pattern. Contouring is at 30-meter intervals.

J. 500 W ANAL. See Chapter IV, Section A. (pp 13). Vertical motion contoured at 2 cm/sec intervals based on +1 cm/sec contour.

K. SIGMA 2. See Chapter IV, Section A.2. (pp 15). Stability analysis in layer 77 mb to 600 mb. Units are the stability parameter, meters squared per second squared. For this chart, the contour interval is 3000 units. Instability increases toward negative values.

L. W WAVE 30 HR PROG. See Chapter IV, Section B.2. (pp 26). Contoured heights at 3-foot intervals. This chart is based on the 06Z or 18Z map and the 36-hour surface forecast.